

Nov. 1879. *Mr. Calver, On the Working of the Speculum etc.* 17

As regards the photographic intensity of these bands when compared with that of the lines between 70 and 80 of the scale, no one can have any doubt of its superiority in the latter case. To a careless examiner it may appear stronger in the first, but this is a deception caused by the great width of the bands.

In answer to objections that may be advanced against these lines in the 3rd and 4th bands as oxygen lines, on account of their lack of intensity, I submit the appearances offered by the picture. I would also suggest that, since both oxygen and nitrogen are really the only non-metallic gaseous elements that approach a permanently gaseous state, we should be prepared from this fact alone to expect them to produce only faint absorption lines in the solar spectrum.

It also seems to me that the picture really gives us the true spectrum of oxygen, for this region, under the conditions existing in the solar envelopes, viz. that it is a spectrum of six faint lines in two bundles, corresponding to those in the 3rd and 4th bands of the picture.

If we admit that the electric oxygen bands corresponding to this position are really composed of lines, and that the attenuated condition of gaseous oxygen in the Sun explains the faintness of oxygen absorption lines, we have no difficulty in accepting the opinion that oxygen is present in the solar envelopes, and that it acts there in the same manner as any other elementary body, and produces its proper dark absorption lines in the solar spectrum.

As regards the appearance of the picture from a photographic point of view, I would say that, if the slit is opened sufficiently, there is no difficulty in obtaining a more pleasing picture with a brief exposure. But, on opening the slit, purity of spectrum disappears, and as the slit is widened the lines fade away, until at last nothing remains but the five unlined bands, as is shown in H. Draper's photograph in *Nature* of August 30, 1877.

That there is nothing peculiar about this photograph of the 3rd order is shown by the fact, that in photographs of the 1st order the resolution of these five bands is foreshadowed, in those of the 2nd order it is partly accomplished, and in the 3rd order the dissection is completed, as you see.

New York, 1879, Oct. 9.

*On the Working of the Speculum for Mr. Common's 37-inch
Silver-on-glass Reflector. By Mr. G. Calver.*

The Speculum recently finished for the 37-inch Reflector gave me an opportunity of coping with the difficulties to be encountered in making a large speculum of this kind. I have found some of these difficulties to be less than I anticipated; and I believe considerably larger instruments might be undertaken with a reasonable prospect of success.

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There never was any doubt whether large glass specula could be as easily mounted as metal specula, for they have the great advantage of being lighter; but the chief question was whether they could be annealed so as to stand the usual treatment in working. If they would stand this, there is no fear of their durability when mounted.

To decide whether the speculum should be metal or glass was, to a certain extent, to venture a risky experiment. For my own part, I had reason to believe that large disks could be obtained properly annealed. Two firms had guaranteed me disks of three or four feet, and since that time they have offered to undertake a five-foot disk.

One obstinate fact, and one I could get no solution of, was the failure of the four-foot French speculum. But in spite of this failure, a 37-inch glass disk was decided on, to be of about $4\frac{1}{2}$ inches thickness.

There was the question, too, of silvering. Mirrors are usually silvered by being suspended face downwards; but I was quite sure that it could be done face upwards and without even taking it from its cell, and that I could thus avoid a great difficulty with respect to silvering.

I had long been in the habit of silvering mirrors face upwards when testing them during the figuring, as it saved both time and trouble, and I consequently devised a plan for silvering the large mirror which unfortunately was the cause of the blowing up of the first disk.

The cell was perforated as if for a Gregorian. I was going to cut a $2\frac{1}{2}$ -inch hole through the glass, and make a gutta-percha plug to fit. This hole was to serve to let off the water and solutions when silvering. A band of stiff paper, coated with something not acted on by the chemicals, was to form a band to hold the solutions. I had tried many things; beeswax is good when pure, but is mostly sold adulterated with oil and rosin; solid paraffin was found the best of all.

I made a strong machine suited to my method of working. I had flatted the back of the disk and got the concave ready for fining, and was, at the same time, edging it and cutting the hole through the centre; but when less than $\frac{1}{4}$ inch in depth had been cut, it burst into hundreds of fragments. The breaking, doubtless, was owing to the disturbance of internal tension.

I was not sure whether removing the skin from the edge or disturbing the centre was the cause of the blowing up, and I therefore tested this question on an $18\frac{1}{2}$ -inch disk, which, on attempting to cut a hole through it, blew up also. I have since had a large disk *cast* with a centre in it, and it answers perfectly; and had the 37-inch been cast in the same manner, it would have answered the proposed plan for silvering.

The 37-inch was ground and polished with a tool 36 inches in diameter and weighing nearly 3 cwt., and the focus—17 feet $7\frac{1}{2}$ inches—out within an inch or two of what was intended.

Before polishing was commenced, a portion of the workshop was covered with calico to exclude dust, room only being left for working. A wooden tunnel, commencing at the door and extending 40 feet on the ground level, was covered with sailcloth to keep out light and air-currents.

The machine was made so that its revolving table could be turned from the horizontal to the vertical position; the speculum was worked in its cell; the whole weighing nearly 11 cwt.

When testing commenced I sat in this dark tunnel to test at the centre of curvature, and the speculum was focussed by an assistant with screws, so that I received in my eye the image of a very minute pinhole in a lamp screen close by my head.

During the polishing and figuring I carefully studied the behaviour of the disk—for flexure—for distortion of figure by contraction and expansion during changes of temperature—and I found the disk as perfect as a 6-inch one, and without a single infirmity. I soon found it would admit of a perfect and permanent figure, and it gave in the early stage a perfect and symmetrical image of an artificial star, which was magnified many hundred times by an eye-piece. These results were gratifying and satisfactory; they at once removed all doubts of ultimate success.

The work of correcting was tedious and trying, especially in the latter stages, when for every few minutes' polishing the whole preparations for testing had to be repeated, and the settling of the mass into its normal state had to be patiently waited for, and often days passed before further advance could be made.

When the figure had advanced as far as necessary for testing at the centre of curvature, the wooden structure was thrown open at the outer end for the purpose of testing on a distant terrestrial object.

The test objects for daylight purposes consisted of a hole punched through a sheet of metal, with a reflector so placed at the back as to reflect the light of the clouds through, so that it appeared as a bright white spot: a spot of whiting and printed paper was used for definition. When the Sun shone I obtained its image by means of a prism with one of its surfaces polished to a small spherical curve. This was made use of because I could not use a bulb, having to look in the direction of the Sun, and not with the Sun behind me.

For testing at night a lamp covered with a metal screen with a hole through it was used. For every advance towards the correct figure it was first tested at the centre of curvature, and then on the distant object. In the latter case it was, of course, used as a telescope proper, by placing a plane at its working focus for parallel rays.

The plan of figuring was that of local figuring and correcting. The polish and surface was obtained with the large and heavy polisher, and corrected with a number of polishers of various sizes and forms to suit every stage of the progress and the tem-

perature of the air &c. If an error of irregularity of figure set in, it was polished out with the large polisher.

The machine I employed was on a principle which was a modification of that used by the Earl of Rosse. I have made five different machines, one of which was on the principle used by Mr. Lassell—an excellent principle; but I have long since come to the conclusion, that no machine can do the final work like the trained hand, and I was gratified to learn, when in conversation with Professor Draper, that his experience agreed precisely with my own on this point.

The fact that, when polishing specula, we use a tool that is somewhat elastic (for there is nothing equal to pitch as a material for the polisher) shows that it is the *form of the polisher* we want to aim at, and the curve of the glass will follow. Therefore the machine, its rates of revolution and strokes, the size and weight of the polishers, their consistency (which depends on the temperature in which they are worked, and the friction) should all be arranged so as to give to the polisher the figure or curve we desire to give the glass surface.

I may state that the 37-inch disk, as an experimental one, answered all expectations and fulfilled all necessary conditions; and I may also state, as the result of my experience, that I see no obstacle to the construction of glass mirrors of very large sizes.

The 37-inch was silvered by Martin's process, and in this way:—

The surface was washed with some of the potash solution, it was then rinsed and sponged with a handful of pure cotton wool, and finally rinsed.

A band of stout brown paper was ready; that part of it to go next the edge for about two turns was painted with hot melted paraffin. This paper band was wound round, and tightly bound round with strong cord, leaving a rim standing up about two inches above the surface to hold the solutions. Water was then poured on to cover and keep the surface till the bath was ready.

The solutions were filtered through cotton wool. I make the solutions very strong; that is, I dissolve the chemicals in $\frac{1}{4}$ or $\frac{1}{8}$ the quantity of water usually given. Thus the filtering is quickly done and the bulk is small. The quantity of water required to make the bath of sufficient depth can easily be added. The bath was about one inch deep at the edge.

When all was ready, the speculum was tilted and the water shot off; quickly brought to the level again, and the solutions poured on. The sinking particles are thus subtracted by filtration, and the light particles will float harmlessly, and nearly all the silver goes to the glass surface. It was well silvered in twenty minutes, then well washed and sponged over with a handful of cotton wool, finally rinsed, left to dry and polish. It was conveniently silvered with the help of one assistant.